JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1979, 31, 253-257 NUMBER 2 (MARCH)

# THE EFFECTS OF NUMBER OF RESPONSES ON THE POSTREINFORCEMENT PAUSE IN FIXED-INTERVAL SCHEDULES

DENNIS L. NUNES, LARRY A. ALFERINK, AND EDWARD K. CROSSMAN[1]

ST. CLOUD STATE UNIVERSITY, DRAKE UNIVERSITY, AND UTAH STATE UNIVERSITY

The present study manipulated the number of responses in a modified fixed-interval schedule by imposing a blackout after each unreinforced response during the interval. The blackout duration was varied, and the duration of the fixed interval was held constant. The subjects were initially exposed to a fixed-interval 300-sec schedule. Blackout durations of 0, 10, and 50 sec were used. Following this, a fixed-interval 30-sec schedule was used with blackout durations of 0, 1, and 5 sec. Under the fixed-interval 300-sec schedule, the number of interreinforcement responses varied over a wider range than occurred under the fixed-interval 30-sec schedule. The duration of the postreinforcement pause decreased as blackout durations were increased and number of responses decreased on the fixed-interval 300-sec schedule, but pause length did not vary with changes in blackout duration and number of responses for the fixed-interval 30-sec schedule. The differences in the effects of blackout duration and response manipulation on the two fixed-interval schedules were attributed to relatively greater changes in the number of interreinforcement responses for the fixed-interval 300-sec schedule.

*Key words:* postreinforcement pause, number of responses, fixed-interval schedule, interreinforcement interval, work period, blackout, key peck, pigeons

Pause length has been extensively studied in both fixed-ratio (FR) and fixed-interval (FI) schedules. In FR schedules, it has been shown that the length of the postreinforcement pause increases as the ratio requirement increases (Felton & Lyon, 1966; Powell, 1968). In FI schedules, the postreinforcement pause has been shown to increase with increases in the length of the interval (Schneider, 1969; Shull, 1971). In an FR schedule, increasing the response requirement increases the length of the interreinforcement interval (Crossman, Heaps, Nunes, & Alferink, 1974). Similarly, increasing the interval of an FI schedule may increase interreinforcement responses.

Several investigators have attempted to separate the number of interreinforcement responses from the effects of the length of the interreinforcement interval (IRI). Neuringer and Schneider (1968) found that the number of interreinforcement responses could be limited on an FI 30-sec schedule if a blackout were imposed after each unreinforced response during the interval. Similarly, they found that they could increase the length of the IRI on an FR-15 schedule by varying the duration of a blackout imposed after each unreinforced response in the ratio. Thus, in the interval schedule, they indirectly decreased the number of interreinforcement responses by increasing the length of the blackout while holding the IRI constant. On the ratio schedule, they held the number of responses constant but increased the IRI by increasing the duration of the blackout. They found that increasing the blackout duration increased the length of the postreinforcement pause on the FR schedule but had no effect on the postreinforcement pause for the FI schedule. Therefore, they concluded that pause length was a function of the duration of the IRI and not of the number of interreinforcement responses.

Crossman et al. (1974) questioned the conclusion that pause length was not influenced by the number of interreinforcement responses in ratio schedules. In this study, a simple FR component alternated in a multiple schedule with a component consisting of two responses separated by a blackout. The blackout terminated when the sum of the blackout duration plus the length of the pause that preceded it equaled the IRI of the preceding FR compo-

[1]The authors wish to thank Patricia Adams for her help in data collection and Mary Ann Terfehr for her help in preparing the manuscript. Reprints may be obtained from Dennis L. Nunes, Department of Psychology, St. Cloud State University, St. Cloud, Minnesota 56301.

nent. Thus, the IRIs for the two components were approximately equated while the number of responses differed. Typically, pauses were longer in the FR component than in the component with two responses separated by the blackout. In addition, the difference between these pause lengths increased as the difference between the response requirements increased. While these investigators confirmed findings that pause length was related to the IRI, the number of interreinforcement responses was also important in determining pause length.

One possible explanation for these discrepant findings is that Neuringer and Schneider (1968) selected a relatively short FI in which the average number of interreinforcement responses varied only from approximately 19 to 3 responses as they increased the blackout. In their 1974 study, Crossman et al. found little difference in pause length when they equated the IRIs for an FR-25 component with a component requiring two responses separated by a blackout. Differences in pause length became pronounced only when the response requirement in the FR component was raised to 50. This suggests that Neuringer and Schneider might have found different results had they used a longer FI, which would have permitted them to vary the number of responses over a wider range. The purpose of the present study was to investigate the possibility that number of responses can be an important variable in determining pause length in longer interval schedules where number of responses could be manipulated over a relatively large range. Clarifying the role of number of responses could have considerable importance for the theory of FI responding.

## METHOD

### *Subjects*

Three White King Pigeons served. During the experiment, the subjects were maintained at approximately 80% of their free-feeding weights. Water was available at all times in the home cage. Each subject had previous experience on FI and variable-interval schedules. The age and sex of each subject was undetermined.

### *Apparatus*

The experiment was conducted in a standard three-key pigeon chamber (Lehigh Valley). The center key was transilluminated by a white light. The remaining two keys were not used and remained dark. A minimum force of about .15 *N* was required for operation of the key. The reinforcer was two 45-mg pigeon pellets delivered by a pellet dispenser to an aperture centered below the middle key. A white light illuminated the aperture during the delivery of the food pellets. A sound-attenuating housing and ventilating fan served to mask extraneous stimuli. No houselight was used. The experiment was controlled and data were recorded by electromechanical equipment. A Digital Equipment Corporation PDP-8 computer recorded postreinforcement pauses.

### *Procedure*

Because the subjects had previous experience on FI schedules, they were immediately exposed to an FI 300-sec schedule. Each unreinforced response during the interval produced a blackout during which the key light was turned off. This blackout was fixed in duration except that if the fixed interval elapsed during a blackout, the blackout was immediately terminated and the next response was reinforced. The reinforced response was not followed by a blackout. Because the subjects seldom responded during the blackouts, the effect of the blackouts was to limit the maximum number of responses which could be emitted during the interval without affecting the length of the interval itself. The blackout durations and the sequence in which they occurred were 50, 0, 10, and 50 sec.

Following completion of the sequence of blackout values, the length of the interval was changed from FI 300 sec to FI 30 sec. The length of the blackouts relative to the duration of the interval was the same as was used with FI 300 sec. Thus, blackouts of 5, 0, 1, and 5 sec were used with the FI 30-sec schedule.

Each blackout duration remained in effect for a minimum of 30 sessions and until the behavior met the following stability criterion. Median postreinforcement pauses were computed separately for each bird for each session. The behavior was judged stable when five consecutive medians showed no consistent increase or decrease. A condition was maintained for all birds until each bird met the criterion. The number of sessions each condition remained in effect is shown in Table 1. The session length was fixed at 50 reinforcers; sessions were conducted seven days a week.

Table 1
Number of Sessions per Condition

| Condition | Number of Sessions |
|---|---|
| FI 300 sec blackout 50 sec | 55 |
| FI 300 sec blackout 0 sec | 30 |
| FI 300 sec blackout 10 sec | 31 |
| FI 300 sec blackout 50 sec | 33 |
| FI 30 sec blackout 5 sec | 58 |
| FI 30 sec blackout 0 sec | 30 |
| FI 30 sec blackout 1 sec | 30 |
| FI 30 sec blackout 5 sec | 31 |

## RESULTS

The length of the postreinforcement pause on the FI 300-sec schedule is shown in Figure 1 as a function of blackout duration for all three subjects. As blackout duration increased, the length of the postreinforcement pause consistently decreased for all subjects. The longer the blackout, the shorter was the length of the pause, including recovery points.

Also in Figure 1, the length of the postreinforcement pause is shown as a function of blackout duration for the FI 30-sec schedule. Under this schedule, changes in the blackout duration had no effect on pause length. This was found even though blackout durations were selected so that the duration of the blackout relative to the length of the FI was the same for both the FI 30-sec and FI 300-sec schedules. The length of the pause was shorter under the FI 30-sec than under the FI 300-sec schedule for all blackout durations.

In Figure 2, the effect of the duration of the blackout on the number of responses emitted during the FIs is shown. Since few responses were made during the blackouts, these responses are included in the data which are presented. On the FI 300 sec, the subjects averaged from 78 to 182 responses per interval with no blackout to approximately 5 responses per interval with a blackout of 50 sec. On the FI 30 sec, the subjects averaged 14 to 21 responses per interval with no blackout but only 2 to 3 responses per interval occurred with a 5-sec blackout. For both FI 30 and FI 300 sec, the number of responses decreased with increases in the duration of the blackout. The effect on number of responses by imposing a short blackout (1 or 10 sec) was greater than the effect of making that blackout duration five times longer (5 or 50 sec).

## DISCUSSION

Based on their data obtained by varying blackout duration in an FI schedule, Neuringer and Schneider (1968) suggested that the length of the postreinforcement pause is independent of the number of interreinforce-

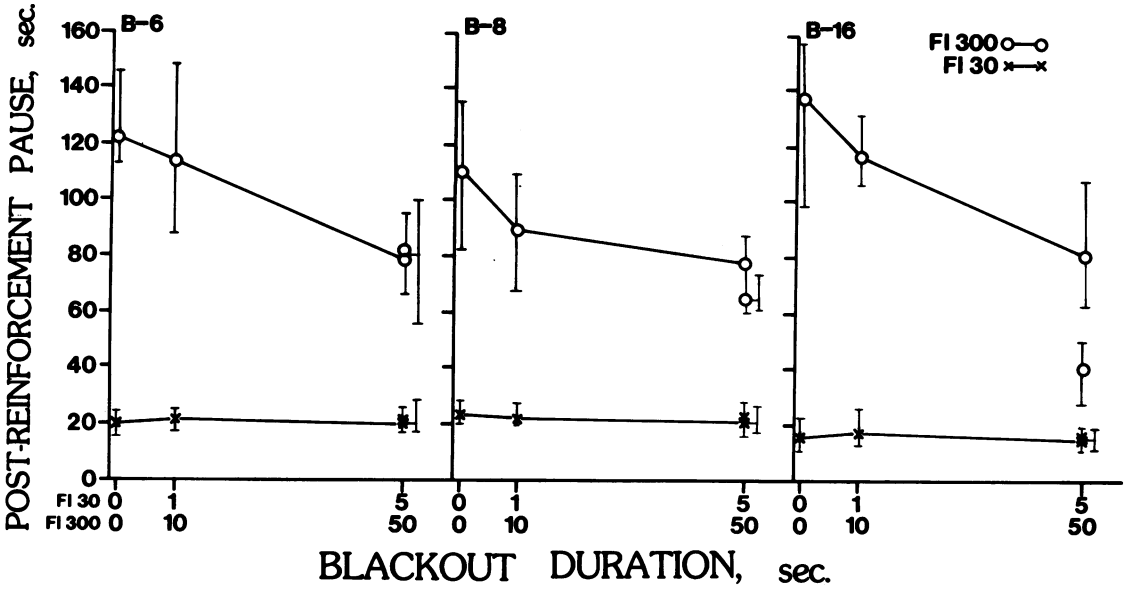


Fig. 1. The length of the postreinforcement pause on the FI 300-sec and FI 30-sec schedules as a function of blackout duration for all three subjects. Only points in the ascending series are connected. The data represent the means for the last five sessions. The vertical lines depict the range around each datum point.

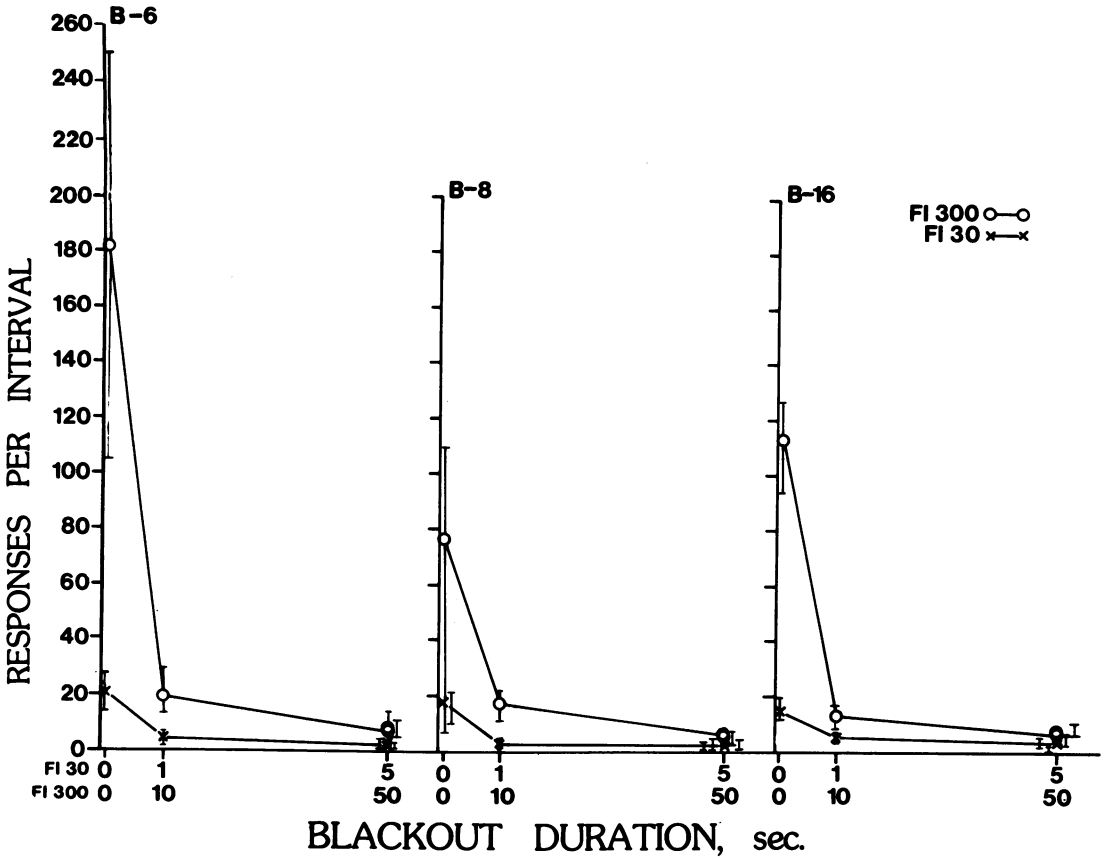


Fig. 2. The number of responses per interval as a function of blackout duration for all three subjects on the FI 300-sec and FI 30-sec schedules. Only points in the ascending series are connected. The data represent means for the last five sessions. Responses during blackout are included in these data. Vertical lines depict the range around each datum point.

ment responses. This conclusion was questioned by Crossman et al. (1974). The differences in the conclusions of these investigators is not easily accounted for. One possibility is that the differences were due to procedural variations in the use of the blackout. Neuringer and Schneider scheduled a blackout after each unreinforced response while Crossman et al. compared pausing in a component with a large number of responses and a component with only two responses separated by a single blackout. Another possibility is that number of responses is related to pause length only in ratio schedules but not in interval schedules.

The present study offers a different alternative. In Neuringer and Schneider's study, the average number of responses per interval varied from a minimum of 3 or 4 responses to a maximum of approximately 19 responses. Crossman et al. and the present study both found that there was little or no difference in pause length when the difference in number of responses was within this range. However, both the present study and Crossman et al. found that pause length did vary with number of responses if comparisons were made between response requirements of 25 or more and 5 or less. These results were obtained with both interval and ratio schedules and were independent of the blackout procedures used. Thus, Neuringer and Schneider's conclusion may be restricted to realtively short intervals containing relatively few responses. If longer intervals containing a larger number of responses are used, the importance of number of interreinforcement responses increases and combines with the IRI in determining the length of the postreinforcement pause. Thus,

those theories of FI responding based on temporal processes (Catania & Reynolds, 1968; Dews, 1970) represent an incomplete account of variables determining pause length within an FI schedule, although responding after this pause may well be determined by the distribution of reinforcers in time independent of response number. Such a possibility would be consistent with Schneider's (1969) two-state analysis of fixed-interval responding. An alternative account of pause length in FI schedules has been suggested by Shull (1971). Shull suggested that the cyclic nature of pause length in longer FI schedules can be at least partially accounted for in terms of the period of time in which responding occurs during the interval. Shull defined the work period as the time between the first response and reinforcement. Shull conceded that one could substitute number of responses for work period without requiring any substantial revision of this analysis. The present study suggests that this substitution is justified.

One alternative interpretation of the present results is that the changes obtained in pause length were due to changes in blackout duration rather than to changes in the number of responses. However, manipulating blackout duration with the short FI had no effect on pause length both in the present study and in Neuringer and Schneider's study. Second, given increases in the response requirement with equivalent IRIs, the short blackouts and larger response requirements are associated with longer pauses than long blackouts and smaller response requirements (Alferink, Nunes, & Crossman, Note 1).

It is also possible that the blackouts reinforced responding and the reinforcing function of the blackout increased with the length of the interval. For example, Brown and Flory (1972) have shown that pigeons will respond to produce blackouts during early portions of the fixed interval and that the probability of this behavior changes with the length of this interval. It is possible that the pause length was shorter in the FI 300-sec schedule because of the increase in the reinforcing function of the blackout. Such an interpretation is consistent with one result obtained in the present study that cannot be explained in terms of differences in response number. Increasing the duration of the blackout from 10 to 50 seconds on the FI 300-sec schedule had the effect of reducing the number of interreinforcement responses from 20 or less to approximately 6 or less. Yet this change resulted in a consistent decrease in pause length even though this same decrease in the number of responses had no effect on pause length on the FI 30-sec schedule. It therefore remains to be investigated whether the effects obtained in the present study are best explained in terms of changes in response number or by changes in the function of the blackout with increases in the FI. In any case, it is clear that the results obtained by Neuringer and Schneider depend on the length of the FI and that their conclusion that pause length is not related to the number of interreinforcement responses is not justified.

## REFERENCE NOTE

1. Alferink, L. A., Nunes, D. L., & Crossman, E. K. *The effect of blackouts and number of responses on pause length on fixed-ratio schedules.* Manuscript submitted for publication, 1978.

## REFERENCES

Brown, T. G., & Flory, R. K. Schedule-induced escape from fixed-interval reinforcement. *Journal of the Experimental Analysis of Behavior,* 1972, **17,** 395-403.

Catania, A. C., & Reynolds, G. S. A quantitative analysis of the responding maintained by interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior,* 1968, **11,** 327-383.

Crossman, E. K., Heaps, R. S., Nunes, D. L., & Alferink, L. A. The effects of number of responses on pause length with temporal variables controlled. *Journal of the Experimental Analysis of Behavior,* 1974, **22,** 115-120.

Dews, P. B. The theory of fixed-interval responding. In W. N. Schoenfeld (Ed.), *The theory of reinforcement schedules.* New York: Appleton-Century-Crofts, 1970.

Felton, M., & Lyon, D. O. The post-reinforcement pause. *Journal of the Experimental Analysis of Behavior,* 1966, **9,** 131-134.

Neuringer, A. J., & Schneider, B. A. Separating the effects of interreinforcement time and number of interreinforcement responses. *Journal of the Experimental Analysis of Behavior,* 1968, **11,** 661-667.

Powell, R. W. The effect of small sequential changes in fixed-ratio size upon the post-reinforcement pause. *Journal of the Experimental Analysis of Behavior,* 1968, **11,** 589-593.

Schneider, B. A. A two-state analysis of fixed-interval responding in the pigeon. *Journal of the Experimental Analysis of Behavior,* 1969, **12,** 677-687.

Shull, R. L. Sequential patterns in post-reinforcement pauses on fixed-interval schedules of food. *Journal of the Experimental Analysis of Behavior,* 1971, **15,** 221-231.

*Received February 27, 1978*
*Final acceptance October 3, 1978*